7.3 An Integrated LDI with Readout Function for Touch-Sensor-Embedded Display Panels

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The use of touch panels with display applications is expanding. It provides a more intuitive user interface and has the advantage of easier and faster entry of the information. Present touch-panel technologies are attached to the front of the display (resistive, capacitive), to the bezel (IR), or to the back of the display (inductive) [1]. These methods require special assembly of extra components and consume additional volume and weight. The front mounted touch-screen reduces display transmission and adds ambient light reflectivity, which result in degradation of the display's front-of-screen performance. Recently several methods have been proposed that enable the AMLCD itself to be touch-sensitive minimizing the need for extra components [1-4]. They are implemented by using an optical sensor array embedded in the TFT structure [1-3] or through the introduction of a resistive touch-sensitive mechanical switch into the pixel [4]. In an optical sensor method, an electric charge is generated in the photo-sensor depending on the intensity of incident light and stored in the capacitor formed in each pixel. In the case of a mechanical switch, current is generated by the touch sensitive mechanical switch formed by introducing conducting spacers on the pixel pad area. The stored charge or the short-circuit current are read out by an A/D converter on the readout IC and are converted into grayscale (or binary) digital image data appropriate for image processing for detection of the touched location.

In this paper we introduce a mobile display driver IC that combines the display driving and readout functions. This device not only drives the display panel but also senses either charge or current signals from the TFT sensor array and converts them into grayscale digital data. It eliminates the need for a readout LSI such that the sensor embedded touch-panel system can be thinner and more compact.

Figure 7.3.1 shows a block diagram of the chip. In addition to the normal display function blocks the chip includes readout function blocks (column readout array block, a global charge amplifier, and an 8b ADC) and sensor control blocks (two 8b DACs for sensor gain control and a sensor scan signal generating block).

Figure 7.3.2 shows the overall readout circuit. The column readout circuit supports both kinds of sensor cells, those with charge output and those with current output. For current signals the column readout circuit integrates the input current from the sensor array for a given period of time, and in so doing converts the current signal into a voltage signal. When the sensor output is charge, the circuit functions as a charge amplifier, and the charge stored on the capacitor in the pixel sensor is transferred onto the feedback capacitor C_i. To suppress the effect of sensor noise and amplifier offsets on the readout, the reset and signal levels are read out differentially. The operation consists in first sampling the reference level V_r during the reset time, and then sampling the signal level V_s related to the sensor output. The timing diagram is shown in Fig. 7.3.3 for the case of a current input. When RESET is 'HIGH', the feedback capacitor C_i is shorted and the amplifier's output voltage becomes equal to the reference voltage, V_{ref}, plus its own offset voltage corresponding to the given input current. When *SPL0* is set to 'LOW', this voltage, V_r, is stored in C_r. If *RESET* is set to 'LOW', the reset switch in Fig. 7.3.2 is open and the integration amplifier starts to integrate the input current. The output signal magnitude decreases with time and the voltage at the falling edge of *SPL1*, V_s, is stored on C_s.

Figure 7.3.2 shows a global charge amplifier to transfer the signal voltage held in each column readout circuit into the ADC. There is only one charge amplifier, which is common to all column readout circuits, and all the column readout circuits are connected to common bus lines, n_{x1} and n_{x2}. It is difficult to transfer the voltage stored in each of the column readout circuits, which are evenly distributed along the long-side of the LCD driver IC (LDI), into the ADC without loss because of the large parasitic capacitcances, C_{x1} and C_{x2}. These capacitances include the C_{sb} and C_{db} of the switches that are off and other wiring capacitances of the long bus line, which is about 2cm long. One method for accomplishing this transfer is to keep the output bus at a reference voltage V_{ref} by utilizing the virtual short-circuit property of the feedback op-amp [5]. Doing this would reduce the effect of the large parasitic capacitance C_x, but would require two separate high-power single-ended op-amps, one for each bus, n_{x1} and n_{x2}. A differential op-amp is used here instead to reduce power consumption. In Fig. 7.3.2 the differential output voltage of the global charge amplifier is given by

$$V_{o1} - V_{o2} = \frac{C_s\left(V_s - V_r\right) + C_x\left(V_{x2} - V_{x1}\right)}{C_f + \left(C_s + C_x + C_f\right)/A},$$

where V_{x1} and V_{x2} are the precharge voltages at n_{x1} and n_{x2}, respectively, and A denotes the amplifier's differential gain. If the two bus lines are equally precharged, and C_f is short-circuited before each transfer by *RST*, then the voltage stored in each column readout circuit can be transferred into the ADC without loss if the differential gain is sufficiently large. The timing diagram is shown in Fig. 7.3.3.

Two chips have been fabricated - one for QVGA and the other for LQVGA (Fig. 7.3.4). The specifications are given in Fig. 7.3.5. Figure 7.3.6 shows a sensor array image obtained from the QVGA chip. For the LQVGA chip the total power consumption is 24mW, about 3mW of it for the readout function.

References:

[1] A. Abileah et al., "Integrated Optical Touch Panel in a 14.1" AMLCD," *Proc. SID*, pp. 1544–1547, 2004.

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[3] T. Nishibe and H. Nakamura, "Value-Added Circuit and Function Integration for SOG (System-on-Glass) Based on LTPS Technology," *Proc. SID*, pp. 1091–1094, 2006.

[4] G. J. A. Destura et al., "Novel Touch Sensitive In-Cell AMLCD," *Proc. SID*, pp. 22–23, 2004.

[5] Y. Degerli et al., "Column Readout Circuit with Global Charge Amplifier for CMOS APS Imagers," *Electron. Letters.*, pp. 1457–1459, Aug., 2000.

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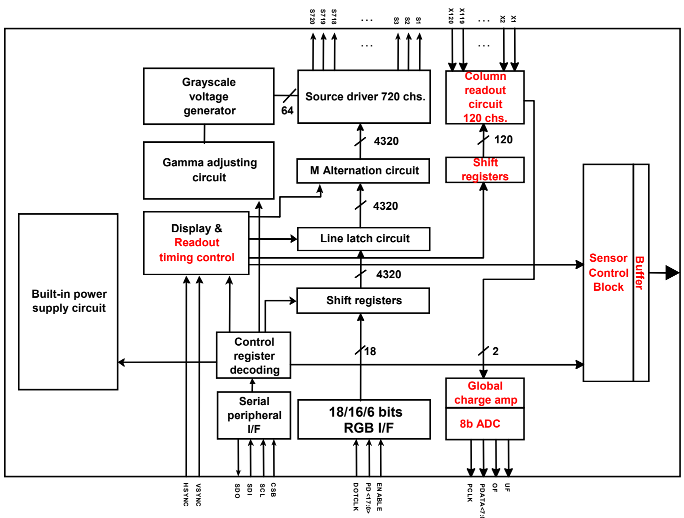

Figure 7.3.1 Block diagram of the readout function integrated LDI.

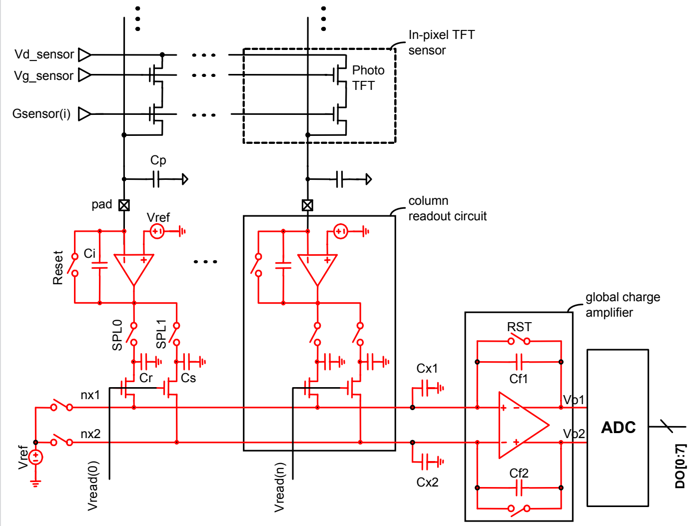

Figure 7.3.2 Readout circuit.

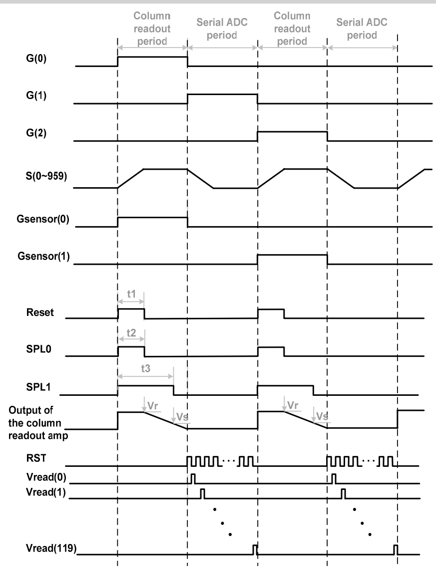

Figure 7.3.3 Timing diagram.

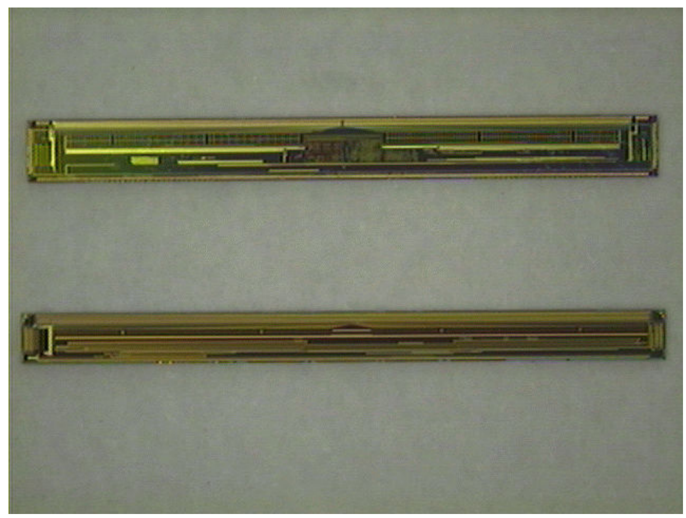

Figure 7.3.4 Chip micrographs (top QVGA, bottom LQVGA).

	LDI for QVGA panels	LDI for LQVGA panels
Process	0.18μm 4M1P high-voltage CMOS	0.13μm 4M1P high-voltage CMOS
number of source output channels	720	960
number of readout channels	120	74
chip size	21,900μm×2,200μm	22,000μm×1,800μm
Sensor embedded display panel	2.45 inch QVGA (a-Si) - display resolution: 240RGB×320 - sensor resolution: 120×160	3.5 inch landscape QVGA (a-Si) - display resolution: 320RGB×240 (272) - sensor resolution: 40×30 (34)
Source output resolution	6b (64 levels)	8b (256 levels)
Sensor readout resolution	8b (256 levels)	8b (256 levels)

Figure 7.3.5 Specifications.

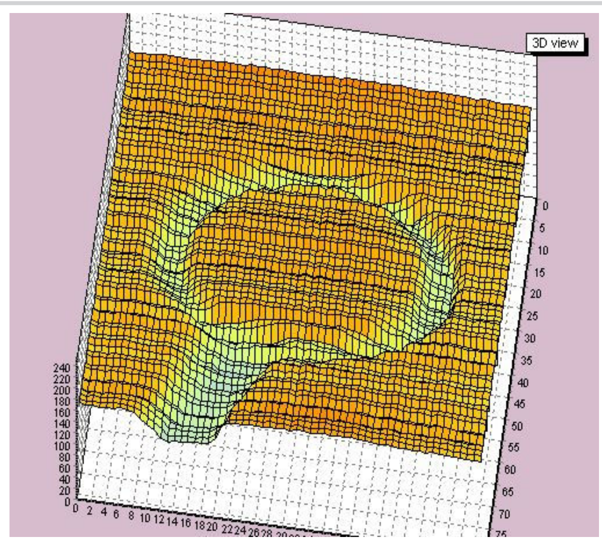

Figure 7.3.6 Sensor array image obtained by placing a mobile phone strip on the display panel.